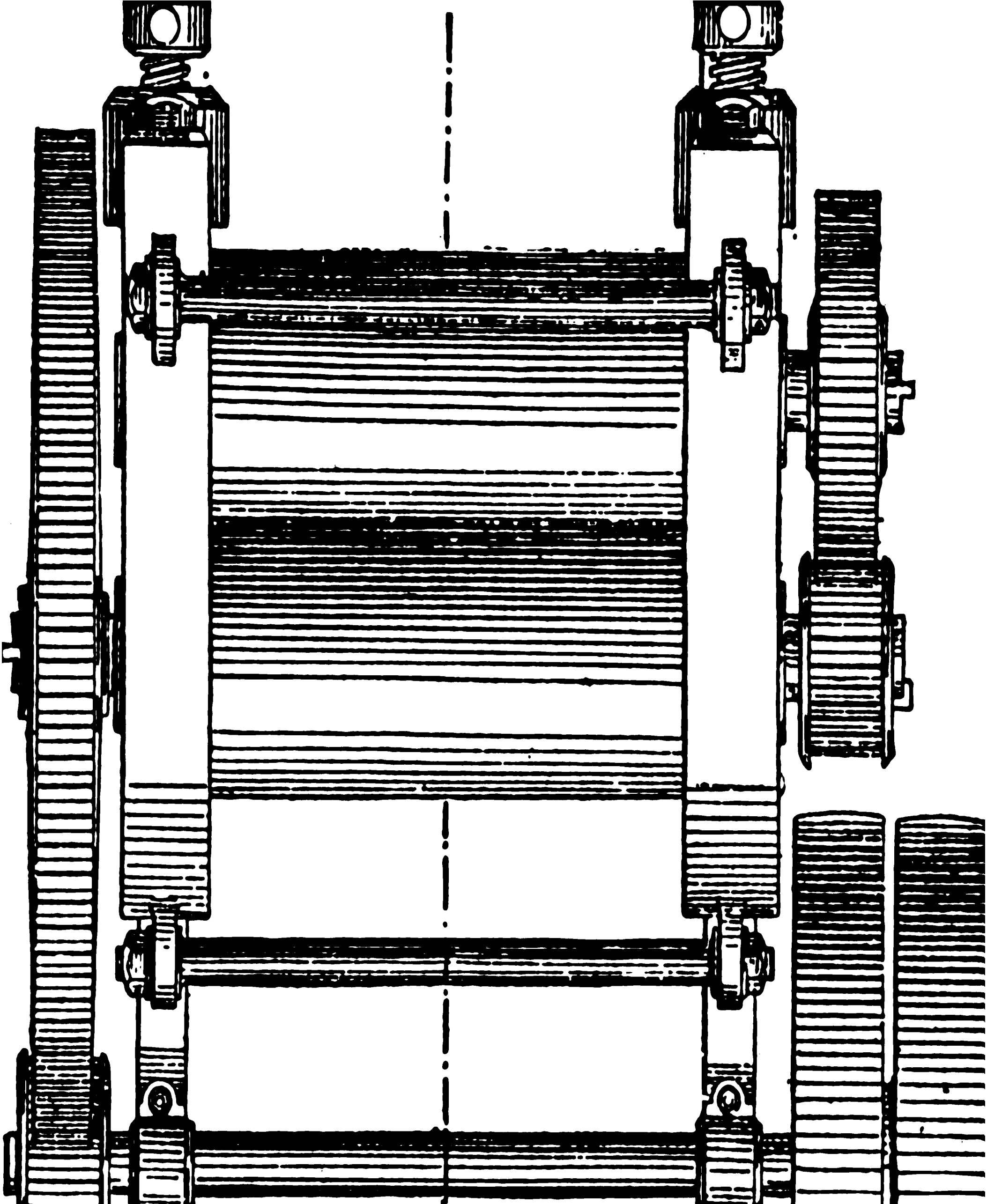

Indiarubber and pneumatic tyre factories

Robert Cumming

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INDIARUBBER AND PNEUMATIC TYRE FACTORIES.

BY

ROBERT CUMMING,

GENERAL MANAGER,

SCOTTISH COUNTY AND MERCANTILE INSURANCE COMPANY, LIMITED.

A Paper read before the Insurance Society of Edinburgh, 15*th November*, 1904.

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By ROBERT CUMMING, General Manager, Scottish County and Mercantile Insurance Company, Limited.

A Paper read before the Insurance Society of Edinburgh, 15th November, 1904.

In the first place, I wish to express to our esteemed secretary and the office-bearers generally my thanks for the privilege of reading this paper before you. Prior to taking up the subject at the request of the former gentleman, my ignorance of it was simply colossal, whatever it may be now, and therefore, whether or not anything that may be said to-night gives information to the hearers of it, it is certain that one person has derived benefit by the acquirement of the knowledge, little though it may be, necessary for the writing of even the baldest and worst possible paper on a subject even now of very great interest and likely to be of even more interest from a commercial point of view as time goes on.

As far as I am aware, this is the first paper dealing with the manufacture of rubber in its fire insurance aspects, and I intend, therefore, to take the liberty of making it, as far as I can, exhaustive, even at the risk of being exhausting, and begin by dealing first with the substance itself.

Indiarubber, or caoutchouc, is the dried coagulated milky juice of various trees and shrubs belonging to the natural orders Euphorbiaceæ, Moraceæ, Artocarpaceæ, Apocynaceæ, Ulmaceæ, and Asclepiadeæ, but there is an appreciable difference between the products of even species of the same order not only in regard to quantity but in quality as well; the quantity of commercial indiarubber depending not solely upon the plant producing it, as many other determining causes may intervene to increase or diminish the yield of the "latex," as the juice is called when it flows from the tree.

Before proceeding to deal with the chemical aspects of the wonderful substance we are considering, it is worth while to turn to the history of its discovery and adaption to the many everyday uses in which we now see it employed, ranging from insulating material for submarine cables to pocket combs and paper knives.

Rubber is first mentioned by Gonzalo Fernandes d'Oviedo y Valdas in his "General History of the Indies" (Madrid 1536), where he refers to "The Indians' game of Batey, which is the same as the game of ball, although it is played in a different manner, and the ball is made of a different substance from that used by the Christians." Father Charlevoise, a Jesuit priest, describes the *Batos*, a species of ball of a solid matter, but extremely *porous and light. It soars higher than our balls, falls on the ground and rebounds much higher than the level of the hand which quitted it; it falls back again, and rebounds once more, although not to such a height this time, and the height of the bounces gradually diminishes.* Antonio de Herrera Tordesillas (1549-1615), in his "General History of the Voyages and Conquests of the Castilians in the East Indies," speaking of the balls used by the Spanish Indians first alludes to their origin from "the gum of a tree." The same author, writing about the conquest of Mexico quotes, as one of the peculiaritiesof Cumana, certain trees which, when punctured, yield milk, changing into gum with a fine smell. Jean de Torquemada, in his book "De la Monarquia Indiana" (Madrid 1615), first mentions a rubber-yielding tree by the name of "Ulequahuitl," a name still used by natives of Mexico to designate the Castilloa Elastica. The Spanish conquerors used the substance procured from the tree to waterproof their cloaks, but found that though impermeable by water, solar heat greatly affected them. Between this time and 1736, some rare samples of the elastic product reached Europe to adorn the cabinets of curio-seekers. It was worth a guinea an ounce. In the last named year, La Condamine, an eminent Frenchman of science, sent to the neighbourhood of the equator in Peru and Brazil by the French Government on a geographical expedition, sent home to the French Academy some rolls of a blackish, resinous mass, known as "caoutchouc." He also sent a memoir with it dealing at considerable length with its properties, and the methods employed in gathering it, and amongst other things says: "The use which is made of this resin by the nation of the Omagnas, situated in the middle of the American continent, on the banks of the Amazon, is still more singular; they

make bottles of it in the form of a pear, to the neck of which they attach a fluted piece of wood. By pressing them, the liquid which they contain is made to flow out through the fluted piece of wood, and by this means these bottles become real syringes." That is the origin of the name given by the Portuguese to the rubber-yielding tree "Pao de Ciringa" and also to the name given to the harvesters of the gum of "Seringarios."

In 1751 the French Academy published the researches of Fresnau, an engineer residing at Cayenne (an island of French Guiana) who continued the work La Condamine was forced to give up, and who seems to have foreseen all the future importance of indiarubber. He studied the real source of the supply, and after much arduous toil at last discovered among the Coussaris Indians the long-sought tree. Describing Indian methods of collecting indiarubber, he says—"They commence by washing the foot of the tree, then they make, with a bill-hook, longitudinal but rather oblique incisions which should penetrate the whole thickness of the bark, taking care to make them one above another in such a manner that what flows from the top incision falls into the one underneath, and so on, until the last one, at the bottom of which a leaf of the Balisier (an American reed) is placed, which is made to hold the liquid by potter's earth, so as to lead the juice into a vessel placed at the foot of the tree."

He gives further details of the processes by which rubber is prepared for the market, but these as well as the above-mentioned process are so much like the processes still in vogue that I need make no further reference to them at this point.

The publication of the result of the researches of La Condamine and Fresnau induced the French botanist Fuset-Aublet to start for Guiana in 1762, and two years afterwards this man of science published his "Flora of Guiana," in which he made known the botanical details presented by the indiarubber tree, to which he gave the name of *Hevea Guyanensis*.

A doctor of medicine in Prince of Wales Island, James Howison, was the first to determine the species that was later called *Urceola Elastica* by Roxburgh, who himself discovered in the forests of the Brahmaputra in Assam, the *Ficus Elastica*, and finally Coffigny was the first to announce the existence in Madagascar of a sarmentose plant of the jasmine species which furnished a milky juice yielding, on thickening, an elastic juice like indiarubber.

While botanists were carrying on their researches, chemists and

others were at work to find means of making use of the raw material brought before them. In 1768 Herrissant and Macquer simultaneously memorialised the Paris Academy on the subject and enumerated Dippel's animal oil, spirits of turpentine, and pure ether as bodies capable of dissolving rubber, which is insoluble in water or alcohol. They proposed to make surgical probes and small laboratory tubes of it. In 1770, Dr. Priestley, an English chemist, called the attention of the scientific, or more properly art, world, to the use of indiarubber for effacing pencil marks, stating that it was sold in cubical pieces of half-an-inch for three shillings each. In 1772 Magellan introduced the substance into France, and as far back as 1775 small cubes of rubber were on sale at stationers' shops, and called in France—*peaux de negres* (niggers' skins), and in England—*indiarubber*, a name still persisting.

In 1780 the experiments of Berniard, a French chemist, continued the work of Macquer and Herissant, and forecasted the many uses to which indiarubber would some day be put. Fourcroy (1735-1809), Berthollet (1748-1822), and Giobert carried on experiments, and Grossard demonstrated the best method of making bottles, tubes, and the like by using thin, narrow strips of rubber. Besson (1791), Johnson (1797), Champion (1811), and Clark (1815) made attempts of varying degrees of success to make waterproof clothing, and in 1820, Nadier, an English mechanic, discovered means by which indiarubber could be cut into thread and elastic fabrics woven from it to take the place of small spiral springs. At last in 1823, Macintosh, founder of the well-known firm still flourishing in Manchester, and whose works I recently visited, discovered and applied a solution of indiarubber in coal tar naptha and thus created the waterproof garment industry which took the name of the inventor. But the problem of the best use of rubber was not yet solved. The early macintoshes were even more remarkable for their powers of adhesion in fastening their unlucky wearer to his seat at inopportune moments than for their waterproof qualities, and for some years were productive of more bad language than anything else. In 1836 Thomas Hancock found that rubber, cut into small strips or shredded and submitted to energetic kneading under the influence of moderate heat, could be reduced into thick masses, that its elasticity could for the moment be suppressed, and that in this state it could be moulded into any desired form. The manufacture of rubber

articles was thenceforward a solved problem, and the discoveries of Rattier, Guibal, Aubert, and Gerard came in quick succession and caused the industry to make rapid progress.

The uses of rubber would have remained comparatively few but for the wonderful discovery of vulcanisation, which opened up an entirely new range of possibilities. Ordinary rubber objects are subject without exception to a great defect arising from the deterioration of their elasticity under different circumstances and conditions. Rubber is very elastic at ordinary temperatures; a thread may be stretched to five or six times its original length and when the stretching force is removed returns to its original size. Cold, however, causes it to lose this property, and if stretching is attempted, the rubber breaks. At summer heat this elasticity is restored. Natural rubber, too, is very adhesive, especially to itself, and this property is useful in indefinitely enlarging threads and sheets. At summer heat this adhesiveness increases and the rubber becomes sticky and pitchy, giving off at the same time a very disagreeable smell. These qualities were fatal to the success of the first attempts at waterproof garments, and natural rubber macintoshes were soon abandoned.

In 1832 the German chemist, Ludersdorf, was the first to discover that *sulphur* removed the viscosity of indiarubber dissolved in turpentine; at about the same time, Hayward, an American, used sulphur to powder indiarubber sheets and thus lessen their stickiness. But neither of these investigators pursued their researches to their natural end, and to Nelson Goodyear is due the solution of the problem of the production of a preparation of indiarubber, neither brittle at low temperatures nor sticky at high temperatures, by methods commercially applicable. In 1839, Goodyear found that by mixing rubber and sulphur and exposing the mixture to a fairly high temperature a substance was produced, elastic over a very wide range of temperature (from below freezing to 248 degrees Fahrenheit) and highly resistant to most chemical re-agents. This process is called vulcanisation, and its discovery gave an impetus to indiarubber manufacture that has continued ever since. Other methods of vulcanisation were found possible, by Parkes among others, who had in 1843 found in carbon bisulphide a better solvent for rubber than any previously known. Parkes also was the first to discover a process of desul-

phurising rubber waste, and finally (1858), after Hancock had in 1846 patented a method of moulding rubber objects, an invention which was the origin of full moulds (buffers, valves, belts, etc.), then of hollow moulds (mostly toys), Goodyear carried the process of vulcanisation further and produced hardened rubber or ebonite, a horny mass not unlike ivory.

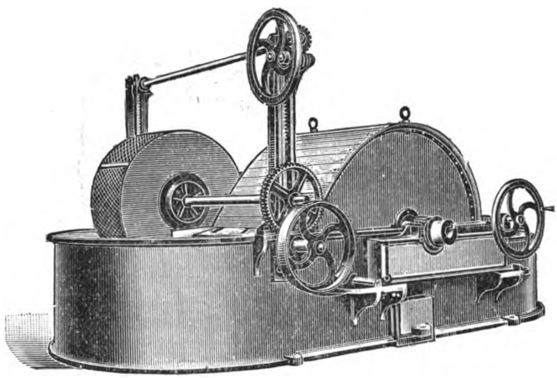
It would serve no useful purpose to go into the geographical distribution of rubber-yielding plants in detail now, but in the exhaustive work of Messrs. Seeligmann, Torillhon, and Falconnet, French experts in various branches of rubber manufacture, any who wish to inform themselves fully will find as much material as the most ardent inquirer can desire. Suffice it to say that a moist, warm climate is essential, and that the zone extending from 30° north latitude to the same degree of south latitude fulfils the necessary conditions, but the finer varieties of rubber are only to be found within the narrow zone of 3° 50′ north to 1° south, where the temperature ranges from 66° to 90° Fahrenheit with a very moist atmosphere. These limits are well within the isotherm of 80° Fahrenheit.

For want of time I must pass over many interesting details of the attempts, successful and otherwise, to acclimatise rubber plants in new countries, and also many particulars as to the method of gathering and preparing the raw rubber for shipment. It must be mentioned, however, that in some districts the tree is felled, instead of being bled to secure its latex, and though the latter process, pursued injudiciously, is injurious, the former is fatal, and, unless the tree is past its best, a most wasteful process. The exceedingly unhealthy climatic conditions that prevail in most rubber-producing countries militate against scientific methods, but until these are largely introduced the production of rubber will less and less meet the demand for it, and the price is likely to rise as it has done for some years back. I cannot help thinking that the scientific production of raw rubber offers a very favourable field for the consideration of the progressive capitalist.

For full details as to its solubility and other physico-chemical properties both in the raw and vulcanised state, a reference to the work already mentioned, of which an English translation (by Mr J. G. M'Intosh, lecturer at the Polytechnic, London) was published in 1903, "Indiarubber and Guttapercha" (Scott, Greenwood, & Co., 19 Ludgate Hill, E.C.), will supply all that

can be desired, either in information on the actual points as to which light is sought or by mentioning the source from which further particulars may be obtained.

Raw rubber reaches this country in a variety of forms, and its principal peculiarity some years ago was the extent of the adulteration to which it was subject. Water, earth, sand, vegetable debris, stones, and even, I understand, occasional half bricks helped to add to the rubber (?) production in the hands of the innocent Indian, but now all the balls or lumps of rubber are cut open at or previous to reaching the place of exportation and consequently only reasonably pure rubber reaches this country. To show the great progress of the industry, I may mention in passing that the imports into Britain in 1830 reached only 23·2 tons, while last year (1903) they were no less than 24,305·25 tons, of a total value of £6,743,866 sterling; while the imports



WASHING AND BREAKING ENGINE (Messrs. ~~James~~ Bertrams ~~& Son~~, Ltd.)

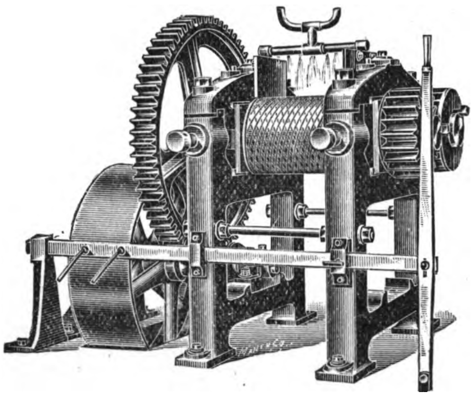
for the first eight months of this year (1904) into the United States were nearly 30,000 tons, and the value, roughly, £8,000,000 sterling.

To give some idea of the rapid increase that has taken place in the value of rubber within the last few years, it may be stated that the price per pound was, in February 1902, 2s. 11d., and in December 1904, 5s. 5d. The increase was not, however, quite continuous, several cases of small decreases having occurred between the dates given above.

The usual first process to which raw rubber is subjected on its arrival at a British factory is that of softening or superficial washing, by keeping it for from twelve to twenty-four hours

in a bath of warm water. The rubber is then sliced by hand or mechanically, and as in the latter case water is a usual adjunct, neither of the processes presents any features specially undesirable from a fire insurance point of view, nor does the storage of raw rubber under suitable conditions. The next process is shredding and complete washing performed by rolling machines, and accompanied by a copious supply of water.

After proper washing the shredded sheet or lacework contains no foreign substance except water, and to complete the washing process it is only necessary to dry it. This is done by stretching the "skins," as they are called, on tight iron wires, or in some cases in stoves at comparatively low temperatures (not

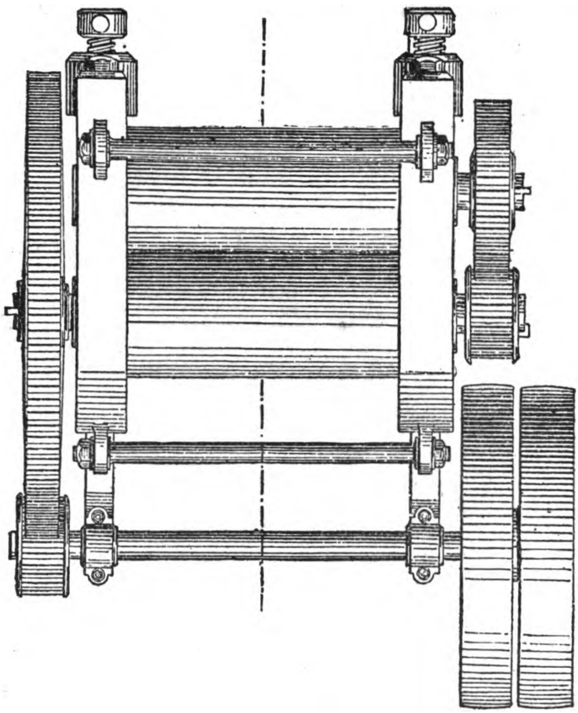


WASHING ROLLS (Messrs. [redacted] Bertram[redacted], Ltd.).

more than 140 degrees Fahrenheit). The drying sheds or stoves require to be well ventilated, and as dark as possible, as exposure to light has a deleterious effect on rubber. After drying, the sheets are folded or rolled, and warehoused in a dry, dark place till required for further treatment. There is considerable loss of weight during washing, varying from 15 to 20 per cent. for high-class rubbers, to as much as 60 per cent. in inferior qualities. Para rubber is the best.

In most modern factories the rubber is next masticated or mixed, and as a high temperature would spoil the rubber, there is no special fire hazard in this process either. After this process the rubber takes the form of thick irregular slabs, and in some factories so important is this work considered that different qualities of rubber, particularly African rubbers,

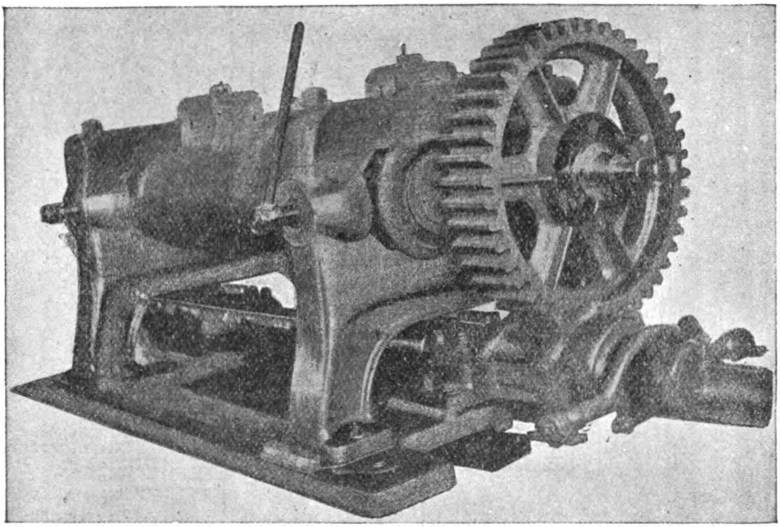
are dealt with separately. The rubber is next mixed with sulphur, sometimes at the end of the mixing or masticating process, sometimes in a different operation, the proportion of sulphur depending upon the use to which the rubber is finally destined in its vulcanised state, and any other substances required for colouring or other purposes are also introduced. The masticated rubber is then formed into regular-shaped plates or blocks by passing through hot rolls (176 degrees Fahrenheit), the blocks varying in thickness according to the end in view.



MIXER—HORIZONTAL ROLLS (Plan) (Messrs Scott, Greenwood & Co.).

Blocked rubber is then stored, and during storage the rubber, somewhat uneven, and in parts stringy at first, becomes of equal texture throughout, and assumes the form of the mould in which it is placed. From block rubber is manufactured sawn sheet and English sheet rubber. By various different machines, all on practically the same principle, and only differing in detail, the blocks are sawn into sheets ranging in thickness

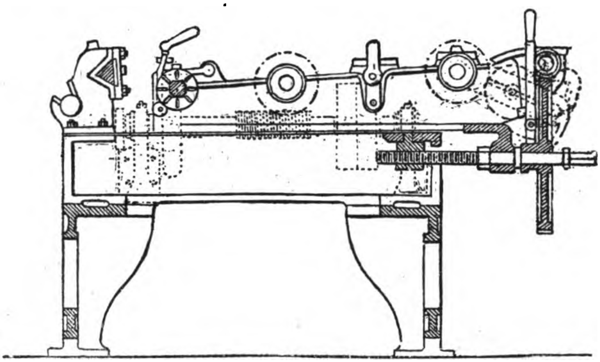
from 4·15 down to 0·18 millimetres. From sheet rubber many different articles are easily made. If edges cut slightly obliquely are pressed together, especially if a brush dipped in benzol has been run over them, they will form a perfectly homogeneous joint on being struck with a small round-headed hammer. Joint is perhaps hardly the correct word to use. The two edges become as completely united as if no division had ever existed. Before articles so made can be put upon the market, however, they must be vulcanised, or they would be subject to the various defects of pure rubber already referred to.



Large Calibre Mixer (Messrs. Scott, Greenwood & Co.).

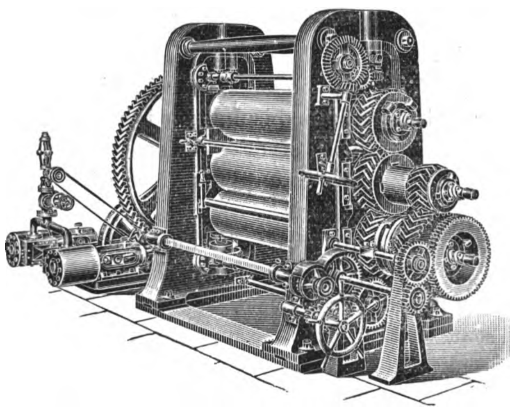
Blocks may be converted into sheets also by lamination or pressing. For this process the cake, when it becomes sufficiently homogeneous in the mixer, is passed while still warm into a calendar. (In passing, it is well to mention that considerable heat is developed by the friction of the rubber in the rolls of the mixer, and that as varying degrees of heat are desirable in the process, according to the purpose for which the rubber is destined, the rolls are hollow, and may be filled with hot or cold water at will.) The rolls of the calender are generally made of steel, and are heated during the whole process, as a

result of which the block is reduced to a sheet of the desired thickness, and in properly made rubber, entirely free of the serious defect of air bubbles. There are also friction calenders in which the rolls revolve at different speeds, and which are



Machine for Cutting Continuous Sheets of Rubber (Elevation) (Messrs. Scott, Greenwood & Co.).

generally used to apply a thin sheet of rubber to canvas and other fabrics for the manufacture of hose pipes, transmission belts, outer tubes of pneumatic tyres, etc. After a fabric has been treated in this way a thicker layer of rubber may be put

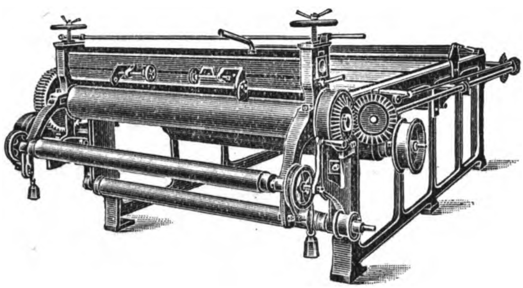


Calender (Messrs. [redacted] Bertram[redacted], Ltd.).

on by passing it through a calender again. There are also calenders which coat both sides of fabric with rubber at one process. By the use of special rolls, laminated sheet is made to imitate the appearance of sawn sheet, for though the former

process may be carried on all the year round and the latter cannot, the superior qualities of sawn sheet for many purposes enable its manufacture to be continued in spite of its greater cost.

The laminated sheet has only comparatively recently been used in the making of rubber thread. Formerly raised sheet was used, an excellent but costly method. The process of raising consists of repeated application of thin coatings of rubber by evaporation of a rubber solution to any suitable fabric, until the required thickness of rubbe is attained. The sheet is then treated with talc and the rubber detached (by moistening with a little solvent) and rolled on a winder. By Sollier's



SPREADING MACHINE (Messrs. ~~James~~ Bertrams ~~& Son~~, Ltd.).

process, and by casting sheets on glass, the disadvantage of having one side of the sheet marked by the threads of the fabric on which it is raised is avoided. In the last mentioned process a very dilute solution of rubber in bisulphide of carbon (1 of rubber to 15 of carbon bisulphide) is used, and care must be taken that the process of évaporation be not too rapid, or the deposit of drops of water on the surface of the sheets would spot and spoil them.

Before proceeding to treat of vulcanisation, it is perhaps better to deal with the chemical composition of rubber, and its action when exposed to various re-agents. Rubber is a hydrocarbon of somewhat uncertain composition, as its exact analysis presents peculiar difficulties to the chemist. The leading article on the subject in the "Encyclopædia Britannica" gives its symbol as probably $(C_{10} H_8)x$, but states that there are no data for the determination of the value of x in this formula. The French work to which reference has already been made states that the correct formula of the fundamental carbide from which rubber is derived is $C_5 H_8$, and that rubber may thus be considered as a mixture of

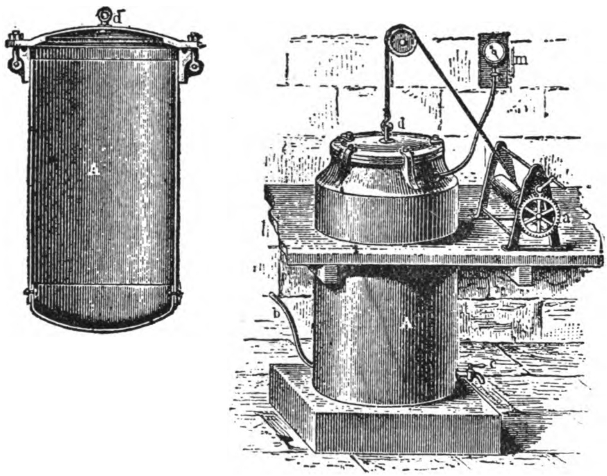
polymeric carbides of high equivalents. In the Journal of the Society of Chemical Industry (30th January, 1904) the formula is given as $(C_{10}\ H_{16})x$, and it is remarked that the x is likely to be replaced by the figure 10. At all events all the varieties of rubber are terpenes or polyterpenes, which, under the influence of atmospheric oxygen and light, partially change into resinous bodies and yield the rubbers of commerce.

Dilute acids or caustic alkalies have little effect on rubber. Concentrated hydrochloric acid, both in the liquid and gaseous states, attacks rubber, but the change it undergoes is but little known. Nitric acid attacks it feebly at low temperatures, energetically at high, colouring it yellow at first, afterwards turning it into a greasy-looking body from which nitrogen is disengaged, and finally converts it into carbonic acid and oxalic acid. By prolonged ebullution the greasy-looking substance is converted into campho-resinic acid. The nitrious vapours act very violently, and rapidly decompose it. Concentrated sulphuric acid acts upon rubber as it does upon cork, and clears the surface even at low temperatures. At high temperatures decomposition is very rapid, with release of sulphurous acid and carbonic acid. A mixture of sulphuric and nitric acid attacks rubber very energetically. Hydrofluoric acid and the organic acids have no action on the rubber.

Chlorine in its gaseous state exerts a very energetic action on rubber, impairing its elasticity, and finally making it hard and brittle. Iodine and bromine exert an effect analagous to that of sulphur, the former being more energetic in its action.

Sulphur is the most important substance of all in the rubber industry, next of course to the rubber itself, and by its use the practically endless varieties of substances adapted to make objects of every description has been rendered commercially possible. If rubber is mixed with either pure sulphur, the alkaline sulphides, the sulphides of alkaline earth, the metallic sulphides, or chloride of sulphur, and the mixture heated, the sulphur is more or less absorbed. According to the quantity of sulphur absorbed and the amount of heat to which the mixture is exposed, the rubber becomes transformed into more or less hard and elastic substances named, in accordance with the existence of these qualities, vulcanised rubber, hardened rubber, ebonite, etc., etc., and all these substances are entirely free, within a very large range of temperature, from the disadvantages inherent in raw rubber.

Raw rubber may, it is true, be vulcanised by the use of other agents than sulphur, such as the halogens, but these bodies are so much more volatile than sulphur at ordinary temperatures, and their action is so much more energetic, that great difficulty exists in obtaining satisfactory results with them; thus sulphur—cheap, easy to handle, and commercially satisfactory in its results—is by far the most extensively employed substance to obtain the valuable rubber products above mentioned. There are quite a number of different processes of vulcanisation all in daily use, but as the highest temperature necessary in any of them does not exceed 320 degrees Fahrenheit, none of them present, under normal circum-



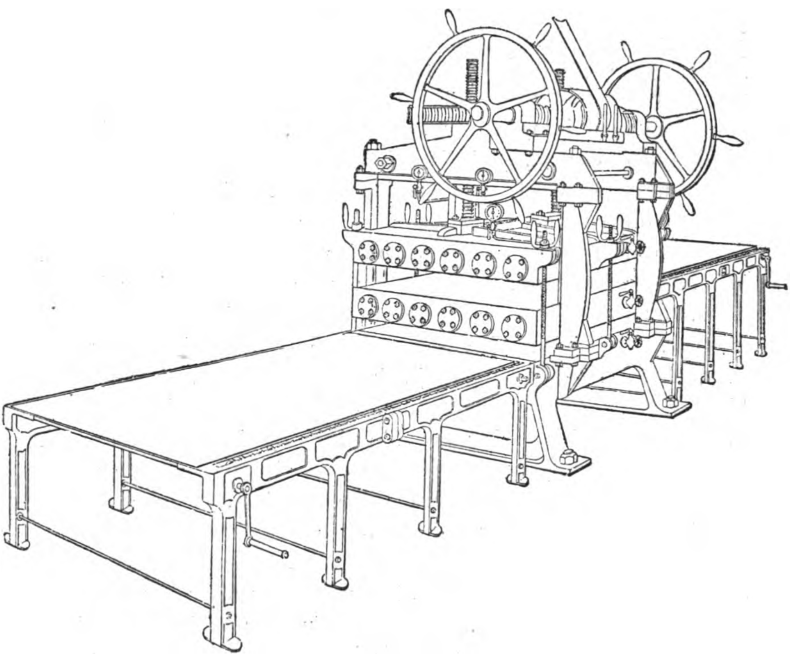
Apparatus for Vulcanising Small Objects by High Pressure Steam (Messrs. Scott, Greenwood & Co.).

stances, any special fire hazard. There is some doubt as to what the process of vulcanisation really is from a chemical point of view, but there is certainly some ground for believing that ebonite is the product of complete vulcanisation, and that the softer products are obtained by arresting the process at various stages.

Vulcanised rubber may be coloured in various ways by the addition of suitable pigments, and may be also deodorised, but the last process, unfortunately, yields only temporary results. Rubber in this state is a bad conductor both of heat and electricity, and for this reason, along with other properties, it is particularly suitable for use as an insulating material. It also resists most chemical re-agents better than normal rubber, but certain of the

metals, particularly iron, copper, and certain alloys, exert a powerful corroding effect on, and are reciprocally corroded by, vulcanised rubber; and for this reason, in electric cables, the rubber is not allowed to come into contact with the copper conductor.

And now, finally, a few minutes must be spared to consider the fire hazard of rubber works more closely than has been done in the passing comments already made while treating of processes. In the first place, it is quite certain that the greatest factor of risk is



Vulcanising Screw Press with Three Plates
(Messrs. Scott, Greenwood & Co.).

not the rubber itself but its solvents, of which mineral naphtha and carbon bisulphide are the most common. The former is a volatile substance, giving off a highly inflammable vapour at ordinary temperatures. This vapour, mixed in certain proportions with air, gives not only an inflammable but an explosive mixture, and, consequently, the methods of handling and keeping naphtha are points to which the fire insurance surveyor must devote particular attention. It is worth noting, however, that once the

rubber is dissolved in the naphtha the inflammability is much reduced, though one fire in the thirty-nine occurring in the ten years 1894 to 1903, of which particulars appear in the annexed appendix, is stated to be due to the dropping of a match into solution. The loss, however, was small. In the *Indiarubber Journal* of 23rd November, 1903, there is an interesting article on this subject, but dealing with it particularly in regard to the question of carriage by rail. The details of an experiment to show the comparatively slight risk of fire arising from flames quite close to a quantity of solution (15 per cent. rubber and 85 per cent. naphtha) are given, but the conditions are hardly severe enough to justify any very definite conclusion. This same article, however, throws a very interesting sidelight on the dangers of another substance used in rubber works—namely, carbon bisulphide or bisulphide of carbon, as it is pointed out that vapour from the latter substance is of great specific gravity, and will accordingly, if opportunity offers, run along a table or a floor until it reaches a flame, and will then transmit a fire with the rapidity of gunpowder. Bisulphide of carbon, therefore, must be most carefully looked after, and any carelessness in its storage or use is bound to lead to disaster. It is interesting to note that only one of the forty-three fires, of which details appear in the appendix, has had ignition of bisulphide of carbon as its cause, and that is a case of electric sparking in a roller machine during dry vulcanising by bisulphide of carbon. Some of the twenty-one fires whose cause is unknown may have been due in some measure to bisulphide of carbon, but I am inclined to think that, like gunpowder and other explosives, its danger is so obvious, not only to property but to persons, that the very great care necessitated by this factor, to a very large extent compensates for the physical hazard. There is further to be taken into consideration the very strict regulations of the Home Office under the Factory Acts as regards the use of carbon bisulphide, which, though only intended to prevent injury to the health of the operatives, also reduce the fire hazard.

There are also risks arising from the various fabrics that are used for the foundations of various rubber goods, but these risks are various as the fabrics, and cannot be dealt with properly within the four corners of this paper. Their use in conjunction with rubber presents no special features, at least as regards the class of works which have been brought forward for your consideration. Cycle tyre factories only differ from other rubber works in

that the fabric they use in connection with rubber is almost invariably canvas, which presents no special or undue features of hazard. It may be added, also, that there is a distinct class of rubber works which I have not dealt with at all. These works use waste or recovered rubber—crumb rubber, as it is called—as their basis of production, and as this means that mixtures including cotton and similar substances, often in a dirty and greasy state, are dealt with, the risks of spontaneous combustion, for one thing, are much greater. Messrs. C. Macintosh & Co., with an experience dating back eighty years (to 1824), have no case of spontaneous combustion, and only one of the forty-three cases from 1st January 1894 to 26th August 1904 is attributed to this cause, so that in crude rubber factories the risk of fire from this cause is not great.

It is estimated by a gentleman well qualified to give an opinion on the subject that there are about one hundred works in the United Kingdom for the actual manufacture of indiarubber goods, but as there is no satisfactory list of such works in existence—many firms describing themselves as manufacturers who are not actually such—it is not possible to give any here. The principal centres of the manufacture are, however, London, Birmingham, Manchester, Glasgow, and last, but not least, Edinburgh.

And now, in conclusion, I must express my obligations for assistance and courtesy to Mr. Stronach of the Advocates' Library, Mr. Woodburn of Messrs. W. ~~R.~~ & R. Chambers, Messrs. Gooding and Hale of the Dunlop Rubber Company, Mr. Clay and the Directors of C. Macintosh & Co., Ltd., Mr. James Kerr of the Surgeons' Hall (to whom the Society is already deeply indebted), Mr. J. M. Barr, Messrs. M'Tear & Co., Messrs. Cruickshank, Son, & Co., Messrs. Brocklehurst & Son, Mr. A. B. Dansken, Messrs J. Goodear & Sons, Messrs. Thomas Howell & Co., the "London and Lancashire," "Northern," "State," and "Union" Insurance Companies, to numerous other individuals, firms, and companies, for negative information, very valuable in itself, but supplied by so many that I must ask to be excused from giving their names; to Messrs. Scott, Greenwood, & Co., for permission to use blocks from "Indiarubber and Guttapercha," and to Messrs. ~~James~~ Bertram~~s & Son~~, Ltd., for blocks of machinery made by them; and last, but not by any means least, to you, Mr. Chairman, and to you my patient auditors, for bearing with me so long. I thank you, one and all, sincerely.

APPENDIX.

List of Fires in Rubber Works for Ten Years 1894–1903 (inclusive).

No.	Amount of Loss.	Cause.	Originated in.	Extinguished by.
		1894		
1	£4300	Supposed ignition of fluff		
2	650	Unknown	Rubber store	Fire Brigade
		1895		
3	750	Unknown	Drying stove	
4	510	Waste rubber igniting	Outside building	Fire Brigade
5	70	Unknown	Drying room	Workpeople
		1896		
6	17	Waterproofing ignited through friction of rollers	Steam engine room	
7	70	Overheating steam pipe		
8	10	Unknown		
		1897		
9	430	Unknown		
10	250	Unknown		
11	440	Spontaneous combustion	Attic	Sprinkler
		1898		
12	1560	Naked light ignited cloth	Warehouse	Fire Brigade
		1899		
13	6875	Supposed men smoking		
14	170	Oily waste ignited		
15	100	Gas explosion	Deodorising stove	Works Brigade
16	400	Unknown	Refrigerator room	Fire Brigade
17	235	Unknown, probably smoking	Drug store	Fire Brigade
18	35	Electric sparks in cloth printing machine.	Spreadiug room	Workpeople
19	25	Match dropped in solution	Solution shop	

List of Fires in Rubber Works for Ten Years, 1894–1903 (inclusive)—*continued.*

No.	Amount of Loss.	Cause.	Originated in.	Extinguished by.
		1900		
20	£5	Unknown	Motor fan	
21	1765	Unknown	Drying room	Fire Brigade
22	1060	Unknown		
23	10	Friction in spreading machine	Cycle tyre rooms	Workpeople
24	40	Electric spark in rollers during dry vulcanising by bisulphide of carbon	Liquor curing shed	Workpeople
25	985	Unknown		
26	6600	Unknown		
27	13,875	Unknown	Vulcanising room	Brigade
		1901		
28	610	Unknown	Probably in old rubber goods store	
29	70	Supposed friction	Spreading room	Workpeople
30	45	Unknown		
31	330	Can of naphtha upset		
32	2	Overheating of drying stoves		
		1902		
33	25	Ignition of vapour off cloth by friction with rollers		Workpeople
34	650	Unknown	Warehouse	Fire Brigade
35	95	Unknown		
		1903		
36	380	Unknown		
37	70	Friction of mixing rolls	Mixing mill	Fire Brigade
38	325	Naphtha fumes ignited from watchman's lamp	Spreading room	Fire Brigade
39	20	Friction in spreading machine	Spreading room	Machineman
		Particulars of Four	**Fires in 1904.**	
40	2900	Unknown	Ball painting and box making	
41	20	Hot ashes near wooden tank		Workpeople
42	2580	Unknown, believed to be light thrown among combustible materials	Yard	Fire Brigade
43	615	Unknown, possibly overheating	Drug rooms	Fire Brigade

N.B.—This list is not to be taken as exhaustive.